International Journal of Mechanical and Production Engineering Research and Development (IJMPERD)
ISSN (P): 2249-6890; ISSN (E): 2249-8001
Vol. 9, Issue 2, Apr 2019, 277-286

INFLUENCE OF THERMAL BARRIER COATING AND MEMS BIODIESEL ON THE PERFORMANCE AND EMISSION CHARACTERISTICS OF SINGLE CYLINDER DIESEL ENGINE

SRINIVAS[1] & ABHIMANYU R POSANGIRI[2]

[1]*Department of Mechanical Engineering, PDA College of Engineering, Kalburgi, Karnataka, India*

[2]*Professor, Department of Automobile Engineering, PDA College of Engineering, Kalburgi, Karnataka, India*

ABSTRACT

The aim of the investigation is to determine the CI engine performance and emission characteristics of methyl ester mango seed biodiesel fueled and zirconia thermal barrier coated single cylinder four stroke diesel engine. The piston, piston head, inlet, and outlet valves were coated with zirconia thermal barrier coating material. The engine was operated for different injection pressures for B00, B30, TBC+B00 and TBC+B30 biodiesels. The experiments were conducted on water cooled diesel engine to determine the indicated pressure, brake thermal efficiency, specific fuel consumption and emission characteristics. The result indicates that the brake thermal efficiency of the biodiesel was slightly lower than the brake thermal efficiency of diesel fueled engine. The brake thermal efficiency of coated condition is higher than the uncoated condition. The specific fuel consumption of biodiesel was more compared to diesel and specific fuel consumption for coated condition is lower than the uncoated condition. The emission charecteristics were lower for coated condition than the uncoated condition.

KEYWORDS: *TBC, Zirconia, Biodiesel, CI Engine & Emissions*

Received: Dec 12, 2018**; Accepted:** Jan 28, 2019**; Published:** Feb 22, 2019**; Paper Id.:** IJMPERDAPR201927

Original Article

INTRODUCTION

The introduction of new technologies has played a role in making advancements to this century-old technology. Lighter and stronger materials, advanced manufacturing processes, improved combustion chamber designs, advanced exhaust after treatment technologies and new computational means for designing, analyzing and optimizing the internal combustion engine are just a few of the advancements have made to achieve significant improvements in performance and emissions of the diesel engines[1-2]. The quantity of the energy acquired from the fuel was not an intended level because of the factors in the combustion chamber of the engine. The availability of fossil fuels were decreasing and increasing the cost of the fuels leads the automotive engineers to turn towards the alternate fuels and also to look for the different methods to improve the performance of the engine. Thus, the biodiesels plays an important role in replacing the conventional fuels and thermal barrier coating in the combustion parts may increase the performance of the engine by reducing the heat transfer to the engine parts. Few research scholars investigated the performance of the biodiesel fuelled and thermal barrier coated CI engine [3-8]. T. Karthikeya Sharma [9] studied the influence of argon gas in the intake air of thermal barrier coated SI engine which results in the increase of the engine performances and decreased in the emissions. The thermal barrier coating enhances the exhaust gas temperature leads decrease in the CO emissions. Vikrant Garud et al., [10]

reported that the thermal barrier coating in the engine piston enhances the peak pressure development to 6 bar and the increases the exhaust gas temperature. The TBCE reduces the heat transfer through the engine parts, this impacted on increasing the brake thermal efficiency by 1.4% [11]. Vinay Kumar Domakonda and Ravi Kumar Puli [12] reviewed the theoretical and experimental conclusions of the TBC engine and suggested that the results are of mixed type thus more research work to be carried out on the thicknesses of the different layers must be optimized to minimize the stresses under service conditions. Can Hasimoglu et al., [13] conducted various experiments on a turbocharged direct injection diesel engine coated with $CaZrO_3$by using diesel and biodiesel fuels and reported that with the LHR diesel and STD diesel conditions the brake thermal efficiency was increased approximately 3%, 4% and 6.5%, respectively. Thermal barrier coatings in diesel engines lead to advantages including higher power density, fuel efficiency, and multifuel capacity due to higher combustion chamber temperature [14, 15]. Zirconates have drawn the attention of several research groups as a promising alternative to YSZ. The main advantages of zirconates are their low sintering activity, low thermal conductivity and good thermal cycling resistance [16-18]. A.K. Agarwal [19] reported that the sulphur content in the biodiesel was very low and non toxic. The thermal efficiency of the biodiesel fueled diesel engine was nearly same as the diesel fuelled engine [20]. The augmentation of the NOx emissions in the biodiesel engine was based on the amount of oxygen content in the biodiesel [21-22]. Thus, in the present study the piston, piston head, inlet, and outlet valves were coated with zirconia thermal barrier coating material. The engine was operated for different injection pressures for B00, B30, TBC+B00 and TBC+B30 biodiesels. The experiments were conducted on water cooled diesel engine to determine the indicated pressure, brake thermal efficiency, specific fuel consumption and emission characteristics.

EXPERIMENTATION DETAILS

The experiment was conducted to determine the influence of injection pressure on performance on methyl ester mango seed biodiesel fuelled CI engine. The experiments were carried out at steady speed of 1500 rpm for comparing the performance of CI engine by varying its injection pressure for pure diesel and for 30% blend of bio-diesel. The biodiesel blend is prepared by adding 30% of methyl ester mango seed biodiesel to the pure diesel for testing. The piston, piston head, inlet and out let valves were coated by 50 micron thickness of zirconia thermal barrier coating ceramic material by plasma spray coating technique as shown in the figure 2. A single cylinder computerized diesel engine is used for the conduction of experiments, which was an electrically loaded, water cooled engine directly interfaced with computer as shown in figure 1. This engine having a facility to varying the parameters like; load on the engine, speed and injection pressure of the engine. The engine was operated for 210, 225 and 250 bar injection pressures for B00, B30, TBC+B00 and TBC+B30 biodiesels. The brake thermal efficiency, specific fuel consumption and emission characteristics were determined and compared. The uncoated piston and coated piston are fitted to the engine for conducting the experiments.

Figure 1: Single Cylinder 4-Stroke Diesel Engine Test Rig with Emissions Testing Instrument

Table 1: Engine Specification

Parameters	Specification
Manufacture	Kirloskar oil engines Ltd. India
Engine	ICEngine set up under test is Research Diesel engine (TV1) havingsingle Cylinder, Four stroke , Constant Speed, Water Cooled,
Bore/stroke	87.5mm/110mm
C.R	12:1 to 18:1
Speed	1500 RPM
Rated power	3.50 kW
Working cycle	Four stroke
Response time	4 micro seconds
Type of sensor	Piezo electric
Crank angle sensor	1-degrere crank angle
Injection pressure	250bar/23 def TDC
Resolution of 1 deg	360 deg with a resolution

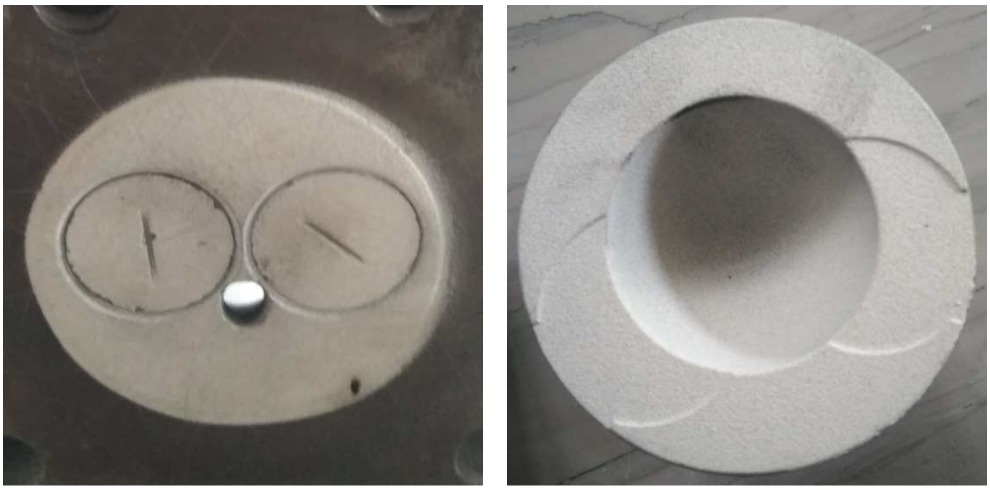

Figure 2: Zirconia Coated Piston Head, Piston, Inlet and Outlet Valves

RESULTS AND DISCUSSIONS

The results of the experimentation are discussed in this section.

Influence of Load and Injection Pressure on Indicated Pressure

The figure 3 illustrates the effect of load and injection pressure on the indicated pressure developed in the cylinder when B00, B30, TBC+B00 and TBC+B30 biodiesels are used for, with and without coating at an engine speed of 1500 rpm and compression ratio of 18. The development of indicated pressure increases as the load on the engine enhances and the indicated pressure for TBC coated condition was higher compared to uncoated condition when B00 and B30 biodiesels were used. The indicated pressure development was higher at 225 bar injection pressure for all conditions. The indicated pressure developed in the engine increases by 13% for B00 biodiesel with coated condition compared to uncoated piston with B00 biodiesel for 9kg engine load. The indicated pressure developed in the engine increases by 5.76% for B30 biodiesel with coated condition compared to uncoated piston with B30 biodiesel for 12kg engine load. The indicated pressure for B30 biodiesel with coated condition increases by 9.74% compared to B30 biodiesel with uncoated condition and the indicated pressure for biodiesel B00 with coated condition enhances by 11.16% when compared to B00 biodiesel with uncoated condition at 225 bar injection pressure.

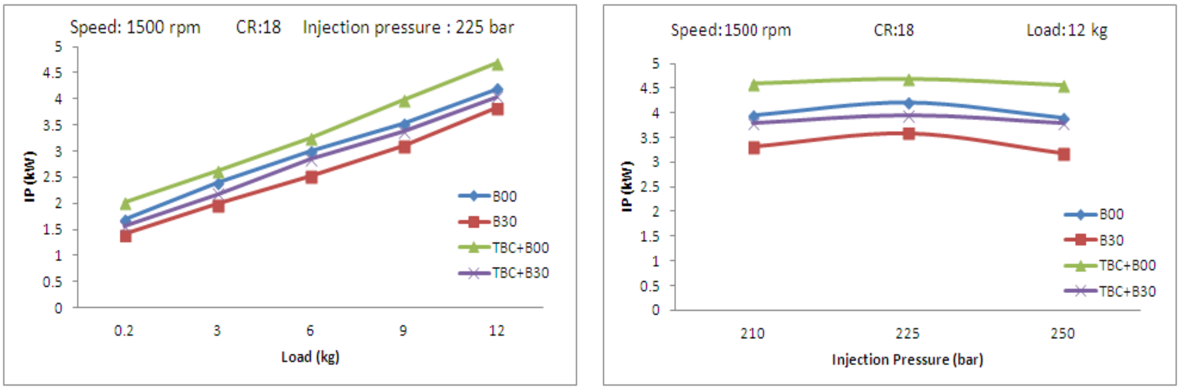

Figure 3: Influence of Load and Injection Pressure on Indicated Pressure

Influence of Load and Injection Pressure on Brake Thermal Efficiency

The figure 4 illustrates the effect of load and injection pressure on the brake thermal efficiency when B00, B30, TBC+B00 and TBC+B30 biodiesels are used for with and without coating at an engine speed of 1500 rpm and compression ratio of 18. The brake thermal efficiency increases as the load on the engine enhances and the brake thermal efficiency for coated condition was higher compared to uncoated condition when B00 and B30 biodiesels were used. The brake thermal efficiency was higher at 225 bar injection pressure for all conditions. The brake thermal efficiency increases by 9.51% for B00 biodiesel with coated condition compared to uncoated piston with B00 biodiesel for 9kg engine load. The brake thermal efficiency increases by 12.47% for B30 biodiesel with coated condition compared to uncoated piston with B30 biodiesel for 12kg engine load. The brake thermal efficiency for B30 biodiesel with coated condition increases by 9.42% compared to B30 biodiesel with uncoated condition and the brake thermal efficiency for biodiesel B00 with coated condition enhances by 11.6% when compared to B00 biodiesel with uncoated condition at 225 bar injection pressure.

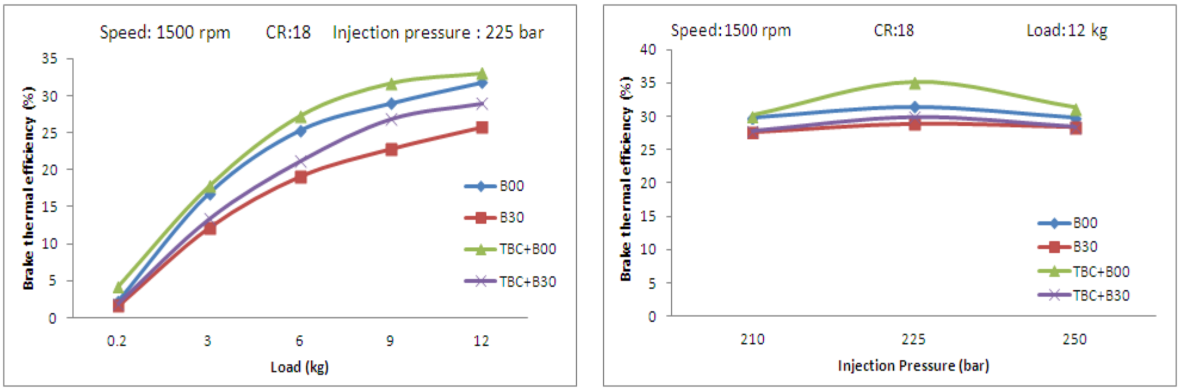

Figure 4: Influence of Load and Injection Pressure on Brakethermal Efficiency

Influence of Load and Injection Pressure on Specific Fuel Consumption

The figure 5 illustrates the effect of load and injection pressure on the specific fuel consumption when B00, B30, TBC+B00 and TBC+B30 biodiesels are used for with and without coating at an engine speed of 1500 rpm and compression ratio of 18. The specific fuel consumption decreases as the load on the engine enhances and the specific fuel consumption for coated condition was lower compared to uncoated condition when B00 and B30 biodiesels were used. The specific fuel consumption was lower at 225 bar injection pressure for all conditions. The specific fuel consumption decreases by 8.57% for B00 biodiesel with coated condition compared to uncoated piston with B00 biodiesel for 9kg engine load. The specific fuel consumption decreases by 5.4% for B30 biodiesel with coated condition compared to uncoated piston with B30 biodiesel for 12kg engine load. The specific fuel consumption for B30 biodiesel with coated condition decreases by 5.45% compared to B30 biodiesel with uncoated condition and the specific fuel consumption for biodiesel B00 with coated condition declines by 13.33% when compared to B00 biodiesel with uncoated condition at 225 bar injection pressure.

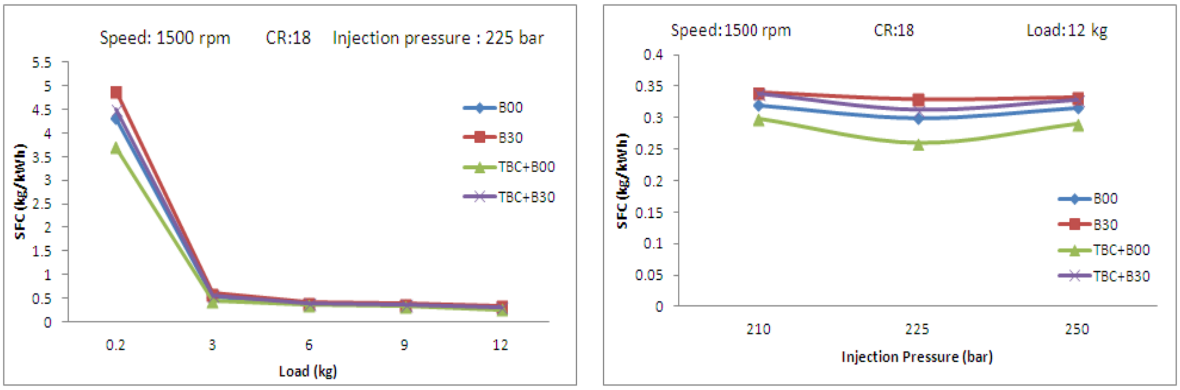

Figure 5: Influence of Load and Injection Pressure on Specific Fuel Consumption

Influence of Load and Injection Pressure on CO Emissions

The figure 6 illustrates the effect of load and injection pressure on the CO emissions when B00, B30, TBC+B00 and TBC+B30 biodiesels are used for with and without coating at an engine speed of 1500 rpm and compression ratio of 18. The CO emissions increases as the load on the engine enhances and the CO emission for coated condition was lower compared to uncoated condition when B00 and B30 biodiesels were used. The CO emissions were lower at 225 bar injection pressure for all conditions. The CO emissions decreases by 12.82% for B00 biodiesel with coated condition

compared to uncoated piston with B00 biodiesel for 9kg engine load. The CO emissions decreases by 18.37% for B30 biodiesel with coated condition compared to uncoated piston with B30 biodiesel for 9kg engine load. The CO emissions for B30 biodiesel with coated condition decreases by 29% compared to B30 biodiesel with uncoated condition and the CO emissions for biodiesel B00 with coated condition declines by 24.5% when compared to B00 biodiesel with uncoated condition at 225 bar injection pressure.

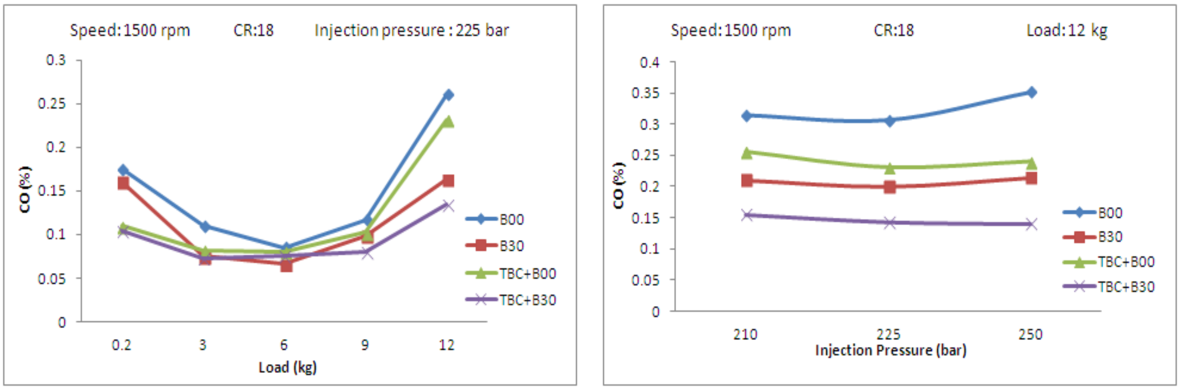

Figure 6: Influence of Load and Injection Pressure on Co Emissions

Influence of Load and Injection Pressure on HC Emissions

The figure 7 illustrates the effect of load and injection pressure on the HC emissions when B00, B30, TBC+B00 and TBC+B30 biodiesels are used for with and without coating at an engine speed of 1500 rpm and compression ratio of 18. The HC emissions increases as the load on the engine enhances and the HC emission for coated condition was lower compared to uncoated condition when B00 and B30 biodiesels were used. The HC emission was higher at 225 bar injection pressure for all conditions. The HC emissions decreases by 6.9% for B00 biodiesel with coated condition compared to uncoated piston with B00 biodiesel for 9kg engine load. The HC emissions decreases by 10.34% for B30 biodiesel with coated condition compared to uncoated piston with B30 biodiesel for 12kg engine load. The HC emissions for B30 biodiesel with coated condition decreases by 5% compared to B30 biodiesel with uncoated condition and HC emissions for biodiesel B00 with coated condition declines by 4.41% when compared to B00 biodiesel with uncoated condition at 225 bar injection pressure [22-25].

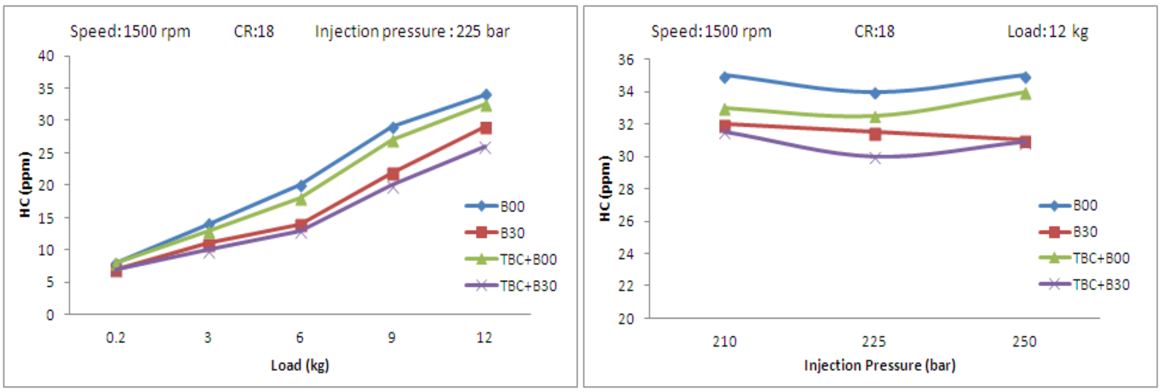

Figure 7: Influence of Load and Injection Pressure on HC Emissions

Influence of Load and Injection Pressure on NOx Emissions

The figure 8 illustrates the effect of load and injection pressure on the NOx emissions when B00, B30, TBC+B00 and TBC+B30 biodiesels are used for with and without coating at an engine speed of 1500 rpm and compression ratio of 18. The NOx emissions increases as the load on the engine enhances and the NOx emission for coated condition was lower compared to uncoated condition when B00 and B30 biodiesels were used. The NOx emission was higher at 225 bar injection pressure for all conditions. The NOx emissions decreases by 3.46% for B00 biodiesel with coated condition compared to uncoated piston with B00 biodiesel for 9kg engine load. The NOx emissions decreases by 4.1% for B30 biodiesel with coated condition compared to uncoated piston with B30 biodiesel for 6kg engine load. The NOx emissions for B30 biodiesel with coated condition decreases by 6.83% compared to B30 biodiesel with uncoated condition and NOx emissions for biodiesel B00 with coated condition declines by 4.02% when compared to B00 biodiesel with uncoated condition at 225 bar injection pressure [22-25].

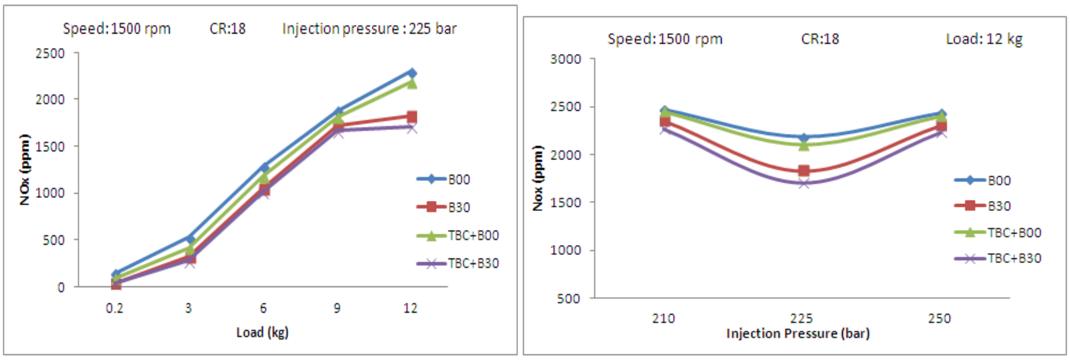

Figure 8: Influence of Load and Injection Pressure on Nox Emissions

CONCLUSIONS

The efficiency and emission characteristics of zirconia thermal barrier coated and biodiesel fueled CI engine were determined. The piston, piston head, inlet and outlet valves were coated with zirconia thermal barrier coating ceramic material by plasma spray coating technique. The development of indicated pressure increases as the load on the engine and brake thermal efficiency enhances and the indicated pressure for coated condition was higher compared to uncoated condition. The indicated pressure developed in the engine increases by 13% for B00 biodiesel with coated condition compared to uncoated piston with B00 biodiesel for 9kg engine load. The brake thermal efficiency increases by 12.47% for B30 biodiesel with coated condition compared to uncoated piston with B30 biodiesel for 12kg engine load. The specific fuel consumption decreases by 5.4% for B30 biodiesel with coated condition compared to uncoated piston with B30 biodiesel for 12kg engine load. The CO emissions decreases by 18.37% for B30 biodiesel with coated condition compared to uncoated piston with B30 biodiesel for 9kg engine load. The NOx emissions decreases by 4.1% for B30 biodiesel with coated condition compared to uncoated piston with B30 biodiesel for 6kg engine load. The NOx emissions for B30 biodiesel with coated condition decreases by 6.83% compared to B30 biodiesel with uncoated condition and NOx emissions for biodiesel B00 with coated condition declines by 4.02% when compared to B00 biodiesel with uncoated condition at 225 bar injection pressure.

REFERENCES

1. *E. Buyukkaya, (2010), Effects of biodiesel on a DI diesel engine performance, emission and combustion characteristics, Fuel 89 (10): 3099–3105.*
2. *X. Meng, G. Chen, Y. Wang, (2008), Biodiesel production from waste cooking oil via alkali catalyst and its engine test, Fuel Process. Technol. 89 (9): 851–857.*
3. *G.R. Kannan, R. Karvembu, R. Anand, (2011), Effect of metal-based additive on performance emission and combustion characteristics of diesel engine fuelled with biodiesel, Appl. Energy 88 (11): 3694–3703.*
4. *F. Wu, J. Wang, W. Chen, et al., (2012), A study on emission performance of a diesel engine fueled with five typical methyl ester biodiesels, Atmos. Environ. 43 (7): 1481–1485.*
5. *Rajneesh Kumar, Anoop Kumar Dixit, Gursahib Singh Manes, Rohinesh Kurana, (2012), Emission and Performance Characteristics of Jatropha Ethyl Ester Blends with Diesel Fuel in CI Engines, IJAuRD, Vol. 2 (2): 34-47.*
6. *Bhaskar Kathirvelu, Sedilvelan Subramanian, Natrajan Govindan, Sampath Santhanam, (2017), Emission Characteristics of Biodiesel Obtained from Jatropha Seeds and Fish Waste in Diesel Engine, Sustainable Environment Research : 283-290,*
7. *Shrirao P N, Pawar A N (2011), Evaluation of performance and Emission characteristics of Turbocharged Diesel Engine with Mullite as Thermal Barrier Coating, International Journal of Engineering and Technology, ISSN: 0975-4024 Vol.3 (3): 256-262.*
8. *Lawrence P, Mathews P K and Deepanraj B, (2011), Experimental investigation on zirconia coated high compression spark ignition engine with ethanol as fuel, Journal of Scientific & Industrial Research Vol. 70: 789-794.*
9. *T. Karthikeya Sharma, (2015) , Performance and emission characteristics of the thermal barrier coated SI engine by adding argon inert gas to intake mixture, Journal of Advanced Research, Vol. 6: 819–826.*
10. *VikrantGarud, Sanjiwan Bhoite, Suraj Ghadage, Nilesh Gaikwad, Devesh Kute, and G. Sivakumar, (2017), Performance and Combustion Characteristics of Thermal Barrier Coated (YSZ) Low Heat Rejection Diesel Engine, Materials Today proceedings Part A, Vol. 4 (2): 188-194.*
11. *KB, S. S., & DV, S. (2016). Thermal Analysis of Advanced IC Engine Cylinder.*
12. *D. C. Gosai, and Dr. H.J. Nagarsheth, (2016), Diesel engine cycle analysis of two different tbc combustion chamber, Procedia Technology, vol. 23: 504 – 512.*
13. *Vinay Kumar Domakonda and Ravi Kumar Puli, (2012), Application of Thermal Barrier Coatings in Diesel Engines: a Review, Energy and Power, vol. 2(1): 9-17.*
14. *Hasimoglu C, (2007), Performance characteristics of a low heat rejection diesel engine operating with biodiesel. Renew Energy, doi:10.1016/j.renene.2007.08.002*
15. *T. Hejwowski, A. Weronski, (2002), the effect of thermal barrier coatings on diesel engine performance, Vacuum, 65: 427-432*
16. *R. Soltani, H. Samadi, E. Garcia and T.W.Coyle, (2005), Develop-ment of Alternative Thermal Barrier Coatings for Diesel En-gines, SAE Paper No. 2005-01-0650.*
17. *J.Wu, X.Wei, N.P.Padture, P.G.Klemens, M.Gell, E.Garcı, P.Miranzo, M.I.Osendi, (2002), Low-thermal-conductivity rare-earth Zirconates for potential thermal barrier coating applications, J. Am. Ceram. Soc., 85, (12): 3031-35.*
18. *R.Vassen, X.Cao, F.Tietz, D.Basu, D.Stover, (2000), Zirconates as new materials for thermal barrier coatings, J. Am. Ceram.*

Soc., 83, (8): 2023-28.

19. *Geete, A., & Khandwawala, A. I. (2014). Exergy analysis for 120MW thermal power plant with different inlet temperature conditions. International Journal of Research in Engineering & Technology, 2(1), 21-30.*
20. *H.Lehmann, D. Pitzer, G. Pracht, R. Vassen, D. Stover, (2003), Thermal conductivity and thermal expansion coefficient of the lan-thanum rare-earth-element zirconate system, J. Am. Ceram. Soc., 86, 8: 1338-44.*
21. *A.K. Agarwal, (2007), Biofuels (alcohols and biodiesel) applications as fuels for internal combustion engines, Prog. Energy Combust. Sci. 33 (3): 233–271.*
22. *H.K. Suh, C.S. Lee, (2016), A review on atomization and exhaust emissions of a biodiesel-fuelled compression combustion engine, Renew. Sustain. Energy Rev. 58: 1601–1620.*
23. *J.F. Sun, J.A. Caton, T.J. Jacobs, (2010), Oxides of nitrogen emissions from biodiesel fuelled diesel engines, Prog. Energy Combust. Sci. 36 677–695.*
24. *J. Xue, T.E. Grift, A.C. Hansen, (2011), Effect of biodiesel on engine performances and emissions, Renew. Sustain. Energy Rev. 15 (2): 1098–1116.*
25. *Lawrence P, Mathews P K and Deepanraj B (2011), Experimental investigation on zirconia coated high compression spark ignition engine with ethanol as fuel, Journal of Scientific & Industrial Research Vol. 70: pp. 789- 794.*
26. *Othman, A. A., Osman, M. A., Wahdan, M. H., & ABED-ELRAHIM, A. G. (2014). Thermal annealing and UV induced effects on the structural and optical properties of capping free ZnS nanoparticles synthesized by Co-precipitation method. International Journal of General Engineering and Technology, 3, 9-16.*
27. *Ramu P and Saravanan C G (2009), Effects of ZrO2-Al2O3 and SiC coating on diesel engine to study the combustion and emission characteristics, SAE International, Paper No. 2009-01-1435.*
28. *L. Wang, X. H. Zhong, Y. X. Zhao, S. Y. Tao, W. Zhang, Y. Wang and X. G. Sun, (2014), Design and Optimization of Coating Structure for the Thermal Barrier Coatings Fabricated by Atmospheric Plasma Spraying Via Finite Element Method, J. Asian Ceramic Soc., 2: 102-116.*